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THE U.S. NAVAL ORDNANCE TEST STATION AT INYOKERN

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General

Some indication of the lavish scale and organisation which will be required for an interplanetary project is afforded by what is, perhaps, the most recent of the post-war "scientific cities." This is the U.S. Naval Ordnance Test Station at Inyokern, California, located some 150 miles north-east of Los Angeles in the Mojave Desert.

The Centre was first organised in 1943 to serve as a rocket testing station attached to the California Institute of Technology, when that body was undertaking a rocket development programme. Since that date, some idea of the tremendous expansion which has taken place can be gleaned from the fact that it is now a city of about 12,000 inhabitants, and comprises some 2,000 buildings, including not only research laboratories and pilot plants, but also a hospital, stores, and complete municipal and recreational facilities. The whole area is virtually a self-supporting modern community, and includes a total of about 1,000 square miles of desert with measurements of some 26 miles from east to west and about 47 miles from north to south.

The functions of the station still place special emphasis on the development of rocket weapons, guided missiles, and aviation ordnance, reflected by the establishment of nine principal range areas for rocket firing, ballistic research, and the operational testing of aircraft. There is, in addition, a 9,000 foot runway, and hangars capable of handling the B 29's which are used for joint Army-Navy high altitude research.

At present, the station employs some 3,800 civilians and 1,000 Naval personnel, which includes about 500 scientists and engineers and 100 Naval officers. Not all of these are employed at Inyokern, however, for the total includes some in the Pasadena area, where the water ranges and facilities for the development of underwater equipment are located.

Michelson Research Laboratory

Of particular interest is the recently constructed Michelson Research Laboratory, named in honour of Dr. A. M. Michelson, the noted American physicist and Nobel prize winner. This building, constructed at a cost of £2 million, is equipped generally with facilities for all types of basic and applied research in aerophysics, electronics, metallurgy, and propulsion for rocket

Aerial View of Naval Ordnance Test Station.
(*Michelson Laboratory in the centre background.*)

and guided missiles, including fire control and guidance systems. The service equipment available includes machine shops, a technical library, material testing facilities, and special altitude weather control laboratories.

A few of the most interesting installations in the laboratory may now be described.

Materials Test Laboratory

A complete radiographic installation is to be operated by this laboratory. For research and production work there will be a one million volt X-ray installation, capable of radiographing seven inches of steel in about 30 minutes. In addition there is also a portable 250,000 volt machine, mounted on a truck, which can be towed to any part of the station where it is required. This unit will penetrate a maximum of 4-inch steel or 10-inch aluminium in one hour. A third machine will be a 140,000 volt unit to be used on very thin material and light alloys. These three units will be housed in a concrete room, approximately 40 × 50 feet, and three stories high. The walls are of 2 foot thick concrete and are lined with ¼-inch lead to safeguard the operating personnel. The concrete door to this room is approximately 13 feet square and 2 feet thick, and can be operated by pneumatic-hydraulic controls in less than a minute.

The purpose of these radiographic installations is to locate the nature and extent of irregularities in materials before expensive machining is started, and so ensure that the materials used are completely sound for their respective purposes.

Other machines available include some large hydraulic testing machines which will enable tension and compression loading on specimens at temperatures from −80 to +1,600° F. Very fine wire can be tested under loads as low as five-hundredths of a pound, and larger specimens up to loads of 400,000 pounds, strains as small as two-millionths of an inch being detectable. A variety of fatigue testing machines will enable tests to be performed under repeated compression and tension loads up to 20,000 pounds 1,800 times a minute.

An assortment of hardness testing instruments are on hand which can be used to test materials ranging from soft rubber to diamonds. Facilities are also in operation to perform vibration, metallurgical and chemical tests on material and accelerated tests to determine wear resistance and weathering resistance. The latter tests produce effects in hours or weeks that would take months or years in actual use.

Heat Treating and Foundry Unit

This unit occupies a total of about one-fifth the whole of the floor space of the Michelson Laboratory, and contains many large furnaces. Long tubes may be heated up to 1,800° F. in pit furnaces 17 feet deep, quenched in huge quench tanks containing 10,000 gallons of oil or brine, and then carefully tempered to produce the required physical properties. Other equipment produces 9,000 cubic feet of inert gas per hour, which may be metered into any furnace to surround the work with a protective envelope of gas which keeps the parts clean and free from scale at temperatures as high as 2,500° F.

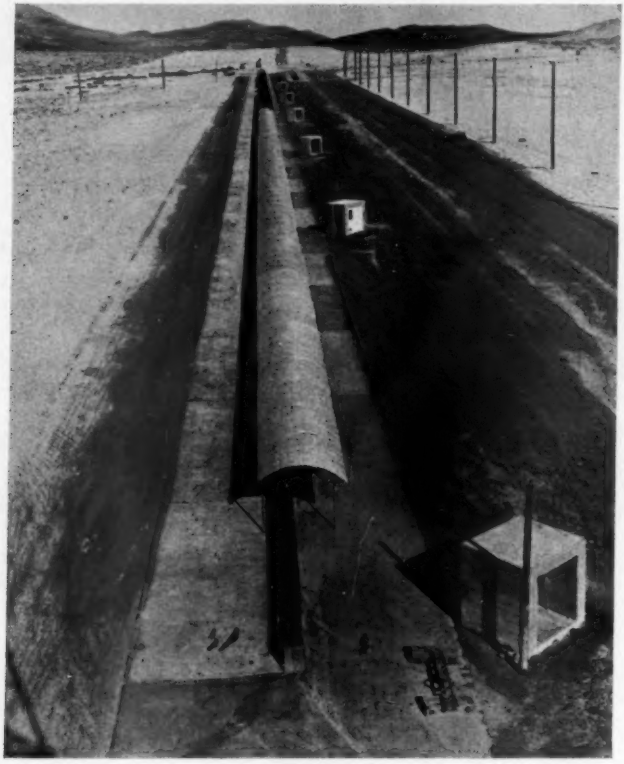
Adjoining the heat-treating shop is the foundry, which is equipped with modern sand handling and moulding equipment, centrifugal casting machines for producing precision castings, and furnaces for melting many different metals and alloys. There is a complete sand testing metallurgical control, and casting inspection system to ensure castings of the necessary high quality required.

Heavy Machine Shop and Equipment

The general machine shops in the laboratory occupy a space of approximately 61,000 square feet in the shop wing, the shop area proper, excluding office space, being about 420 feet long.

A 15-ton bridge crane operates down the full length of the centre, and the heavy machine tools have therefore been located to provide the necessary access to them by this crane. Altogether, a total of about 180 machines have been installed, including 50 lathes (ranging from a jewellers lathe to a 30–60-inch gap lathe with a 21-foot extended bed). The preponderance of these are in the 14 and 16-inch class, but there are 2 20-inch, 3 24-inch, 1 30-inch, and 2 36-inch (one with a 16-inch hollow spindle). There are also some 19 milling machines, while drills range from sensitive bench types, through single

and multiple spindle floor types, to an 8-foot arm radial. Other machines include a jig borer, die duplicator, several engraving machines (including a three-dimensional model), a vertical shaper and 4 horizontal shapers. The



1,500 feet Rail Rocket Launcher.

heavy duty machines are 1 60 × 60 planer with a 21-foot stroke, a 36-inch openside planer with 17-foot stroke, a vertical boring mill swinging 8 feet, a 42-inch vertical turret, a 4-inch bar horizontal boring mill, and a 400-ton hydraulic drawing press.

There is also quite a comprehensive line of grinding machines, for the most part enclosed in a temperature controlled room. The sheet metal shop has, besides the usual variety of power equipment, a 75 KVA spot welder, a 200 KVA seam welder, a 3/16 × 10-foot press brake, a 3/16 × 10-foot shear, two punch presses, and a spinning lathe.

The instrument shop and the master gauge laboratory are also in temperature controlled rooms, the latter containing all the primary measuring equipment and standards. Besides master gauge blocks, supermicrometers, thread gauges and so forth, there are a measuring machine (accurate to 0·000002 inches), a dividing head to measure angles with an accuracy of 2 seconds of arc, a thread lead tester, a universal internal comparator and an optical comparator.

Although not actually located in the laboratory, but in an adjacent building, there is also a welding shop equipped to perform welding and brazing operations on all kinds of materials, and a paint shop equipped with a water wash spray booth and a baking oven.

Weather Test Rooms and Altitude Chambers

Under construction at present are the all-weather and altitude testing rooms, which will be used to simulate sand storms, salt spray, wind, and altitude changes to any degree and in any combination. This is to be accomplished by six separate units, which are either in the design or production stage.

The first unit, at present under construction, is a large laboratory type altitude chamber measuring some 15 feet × 12 feet × 10 feet high. This chamber can be adjusted for any point between 0 and 50,000 feet and within temperatures from +125° and −80° F. A climbing rate of 10,000 feet per minute and a diving rate of 1,500 feet per second can be simulated. The humidity can be controlled between 20 and 95 per cent.

The second unit simulates the ram effect of diving, and should be capable of producing Mach Nos. up to 4, while a third unit is a small instrument type altitude chamber about 3 feet × 4 feet × 3 feet, which has the same characteristics as the first unit already mentioned.

The three remaining units will be able to duplicate all types and combinations of weather ranging from the 60 m.p.h. gale to the desert sun and the arctic storm. It should be possible (through the use of a fan included with the large altitude chamber) to test small models at speeds of supersonic magnitude.

Organisation of the Station

The station is divided primarily into three main technical departments, with other subdivisions wherever considered necessary. These main departments are as follows:—

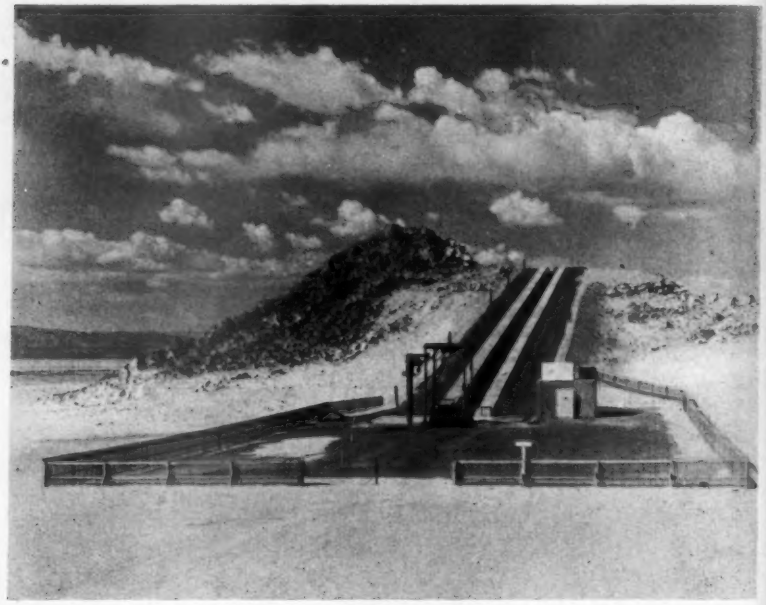
(*a*) *Explosives Department*

As its name implies, the principal work performed by this department is on rockets and propellants, and the operation of the extensive pilot plant equipment.

(*b*) *Experimental Operations and Development Department*

The Experimental Department consists of some 600 civilian scientists and 400 officers and men. It is organised into four divisions:—

1. Measurement, and Aviation Ordnance, at Inyokern.
2. Guided Missiles, and Underwater Ordnance, at Pasadena.



450 feet Launching Ramp.

The department conducts research and development in the fields of aviation ordnance, aviation fire control, underwater ordnance and water entry, guided missiles, surface and air launched rockets, electronic instrumentation and control, and photographic instrumentation. It evaluates guided missiles, rockets, aircraft fire control systems, torpedoes, launchers, blast damage, and aircraft performances. It develops instruments, and operates all aircraft, ground ballistic, and underwater ranges, and provides basic training in the use, of experimental weapons.

(*c*) *Research Department*

The Research Department has really a two-fold duty, first to obtain and evaluate the knowledge required to carry out the assignments given to the station, and secondly to further new discoveries and applications of existing techniques. To fulfil these responsibilities, the department is divided into five technical divisions, physics, chemistry, mathematics, applied science and ballistics, and is manned by a staff of approximately 130 scientists.

In addition to the purely military objectives with which the station is closely associated, it is refreshing to find that the terms of reference of the Research Department include "to pursue fundamental research in the interest of scientific objectives, to attract and retain outstanding scientists and to enhance the prestige of the Navy and station in the scientific world."

A few words might usefully be added regarding the work of the mathematics section, which falls under this department. The establishment of a separate section for this purpose grew out of the need for a readily available group of consultants to assist and advise in the theoretical aspects of ordnance development work. Problems in a great variety of fields, such as elasticity, hydrodynamics, theoretical mechanics and thermodynamics, among others, frequently arise, and mathematical methods of attack need to be devised.

A further major activity of this section is that of the application of statistical techniques in the planning and analysis of tests and experiments. Instruction in statistical theory and practice is given to the station personnel engaged in tests, and assistance is provided in the analysis of especially difficult or unusual problems. Recent war-time developments in sequential analysis and quality control have also been introduced.

The responsibility for analysing weapon effectiveness, developing criteria for evaluating new systems, and studying functional requirements of ordnance equipment is another main function falling upon the mathematics section. Work of this nature requires a study of all the test work previously done, and the synthesis of results into accurate characteristics.

The last main responsibility of the section lies in the field of large-scale mechanical computations. A complete I.B.M. installation has been provided for the use of all departments. These machines are particularly helpful in the speedy analysis of data obtained from the firing ranges, as they make practicable methods of analysis impossible by hand computation, and in addition, ensure much greater accuracy. To assist the solution of more difficult problems, arrangements have been made for differential analysers and electronic supercomputers located elsewhere to be made available.

Underwater Ordnance

Another new research facility lies in the water ranges, located at Morris Dam Reservoir, near Pasadena, where there is deep water suitable for torpedo and other experiments. The growing importance in Naval warfare of projectiles which pass from air to water has brought prominence to many difficult problems associated with water entry, *e.g.* the erratic behaviour of projectiles, failure of structures and the malfunctioning of controls.

Of a particular interest, is the new variable-angle launcher, built to make possible quantitative water entry studies for a wide range of entry angles and at ranging velocities. Design work on the launcher was commenced in 1945, though actual construction did not begin until April, 1946. In this, space has been provided for the eventual installation of a wide range of launching devices for torpedoes, rockets, guided missiles, and other projectiles. Instrumentation, controls, and handling equipment have been built to permit a rapid and accurate testing. Motion picture and still cameras have been located to give a complete photographic record of each launching.

Largest Ram Jet leaving the Launching Rocket.

(This ram jet flew at supersonic speed at the first Navy test at Inyokern. Before it could operate efficiently, it was boosted to supersonic speed by a solid propellant rocket, which then dropped off, leaving the ram jet to continue under its own power.)

A few particulars of the more important characteristics of the launcher are as follows:—

Size of launching tube, 22·5 inches diameter × 300 feet long.
Projectile size, 22·42 inches diameter or smaller.
Range of water entry angle, 0 to 40 degrees.
Range length, 3,000 feet.
Water depth at projectile entry point, approximately 150 feet.
Possible variation in azimuth, 0 to 22½ degrees.
Air flask for launching, 500 cubic feet at 1,000 psi maximum working pressure.

The research data expected to be obtained should enable designers to select projectile shapes, design for known shock conditions on structures, gyros, bearings, seals, etc., in any given set of operating conditions.

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THE ATOMIC ROCKET—I

By L. R. Shepherd, B.Sc., A.Inst.P. and A. V. Cleaver, A.R.Ae.S.

1.—Introduction

The object of this paper is broadly to examine the possibilities of applying nuclear energy to rocket propulsion, but first it may be worth while to recapitulate briefly the reasons why such a development is necessary for the ultimate realisation of interplanetary flight.

Dr. Alvarez, the noted American physicist, has remarked that if and when space-ships with an atomic drive are developed: "it will be only after engineers have reluctantly chosen the difficulties of using atomic energy in favour of the impossibility of using chemical propellants for the purpose." This observation was made during the course of an address in which the speaker implied that he believed the atomic rocket would eventually be realised, although the difficulties were immense, simply because the impossibility of retaining purely chemical techniques was apparent. Succeeding sections of this present paper should provide some further evidence in support of the first two parts of this contention; as for the last part, it is hoped that the following brief argument will be accepted as a convincing demonstration of its truth. (The basis of the argument will be revealed in detail by reference to any of the classic works on astronautics.)

The performance capabilities of any rocket projectile may be specified by means of the equation:—

$$v_c = v_e \log_e \frac{M_o}{M} \qquad \text{.....(I.1)}$$

where:—

v_c = A "characteristic velocity."

v_e = The effective exhaust velocity, assumed constant.

$\frac{M_o}{M}$ = The effective mass ratio.

If the rocket is of simple one-step design, then the "effective" mass ratio is obviously the ratio of the take-off mass ($=m_o$, say) to the remaining mass (m) at all-burnt. For a multi-step design, the situation is rather more complicated, but for our purpose it will be sufficient to consider the ideal case in which

(*a*) the next step commences firing immediately after the previous step has ceased;

(*b*) the structural mass of any individual step is negligible compared to the other masses involved. (The quantity m for any given step is therefore comprised by the payload plus the propellant mass of all the subsequent steps.)

On these simplified and ideal assumptions, the overall effective mass ratio will be given by:—

$$\frac{M_o}{M} = \left(\frac{m_o}{m}\right)^n \qquad \text{.....(I.2)}$$

where the rocket has n steps, each of an individual mass ratio $= \frac{m_o}{m}$.

As for the "characteristic velocity" (v_c), it will be obvious from the foregoing that the rocket would be physically capable of accelerating up to this final velocity *in vacuo* and in the absence of any retarding gravitational field, if its propellants were all continuously expended. Some further consideration will show, however, that v_c can also be regarded in another way, which affords a very convenient method of carrying out rocket performance calculations.

When a rocket is employed on any particular mission, each task which it is called upon to do can be regarded as equivalent to the need to impart a certain velocity to it. A space-ship undertaking an Earth–Moon round trip would, for example, have to be capable of:—

(*a*) Attaining "escape velocity" from the Earth. (=11·3 km./sec.)

(*b*) Making up the air resistance loss due to its outward passage through the Earth's atmosphere.

(*c*) Making up the gravitational retarding loss due to its departure at a finite acceleration.

(*d*) Braking during the approach to the Moon to destroy its velocity of arrival in order to make a safe landing.

(*e*) Attaining "escape velocity" (=2·4 km./sec.) from the Moon, on the return take-off.

(*f*) Braking during the approach to the Earth, so as to enter the atmosphere at a safe speed and land. (But for the retarding influence of the atmosphere, the equivalent velocity requirement for (*f*) would be the same as for (*a*), just as (*d*) and (*e*) are equal.)

(*g*) Making any necessary course and attitude corrections during both the outward and return trips.

Each of these tasks (*a*) to (*g*), then, is equivalent to a velocity requirement, and the sum of all these is the "characteristic velocity" of which such a rocket must be capable, even though it would never be required in practice to travel at such a speed. It will readily be appreciated that true interplanetary voyaging will require much more than the mere attainment of escape velocity; the following table summarises approximately the characteristic velocities needed for various rocket missions.

TABLE I

Mission	v_c (km./sec.)
Long-range missiles	5–10
Orbital "space-station" (incapable of safe return landing)	10
Escape rocket (incapable of safe return landing)	13
Earth–Moon return trip, *without* lunar landing	25
Earth–Moon return trip, *with* lunar landing	30

Return visits to other planets would call for even greater characteristic velocities, 40 km./sec. or more.

Even these rough figures give an adequate indication of the ascending scale of difficulty of the various types of mission which will be attempted in the future. They can be employed to show that the chemical rocket, while it may (given adequate development) cope with the first three of the cases cited, has little practical hope of satisfying the requirements of the last three.

The best modern chemical propellants and motors, as so far employed on anything beyond a laboratory scale, give values of effective exhaust velocity around 2 km./sec. There is good reason to hope that eventually this figure may be as much as doubled, this hope being founded on theoretical calculations and laboratory tests of new propellant combinations. Equally, however, all these same data serve to show that this hope of an eventual 4 km./sec. is, if anything, optimistic. Still higher values are prohibited by considerations of the working temperatures and pressures involved, and even if this were not so, a still more fundamental consideration intervenes—there simply is not sufficient energy available in any chemical reaction to give the exhaust products a greater velocity, after allowing for inevitable losses.

Turning now to considerations of mass ratio, we note that V.2 gave a value of 3·4, while on the projected American "Neptune" rocket it is hoped to attain 4·5 when only a very small payload is carried. Optimistically, we might hope that a value of 5·0 might be possible at some future date. If this value applied for each individual component of a three-step rocket, then from I.2 we find that the overall effective ratio would be approximately 125, giving (from I.1) a possible characteristic velocity of 19 km./sec., if the exhaust velocity were as high as 4 km./sec.

It may be argued that more than three steps could be employed, or that better mass ratios than 5·0 may become possible for the individual steps. There is no space here, however, to do more than reiterate the belief that the latter possibility is unlikely, for rockets carrying an appreciable payload (especially if the propellants are of low density—as is probable for the very high exhaust velocity assumed). As for the use of more steps than three, this would of course be possible, though it would lead to considerable design complexity. Moreover, it should never be forgotten that obtaining better performance in this way inevitably involves a trend towards huge take-off masses for any worthwhile payload. Thus, while small instrument rockets may be designed with a large number of steps, it seems rather improbable that very large ones, of the nature of manned space-ships, will use more than three.

It is conceivable that a limited number of extremely expensive interplanetary expeditions, using huge chemical rockets with many steps, might eventually have been undertaken in the absence of any preferable alternative. Indeed, a study of the effects in past history of the questing spirit of mankind tempts one to the conclusion that this is very probable. Nevertheless, there are obviously very powerful influences at work which make it still more probable that a great effort will be put into the attempt to find means of generating higher exhaust velocities than the 4 km./sec. which may ultimately be possible from chemical fuels. This statement leads inevitably to a study of the possibilities of nuclear energy.

2.—Fundamental Considerations on Use of Nuclear Energy

The release of nuclear energy takes place according to either of two known processes, viz.

(*a*) by spontaneous radioactive disintegration of unstable nuclei; or

(*b*) by nuclear reactions, consequent upon collisions between nuclei or nuclear particles.

The process (*a*) goes on continuously in all radioactive substances, and there is, of course, no minimum limit to the quantity of material which must be present in order for the reaction to proceed. Unfortunately, however, there is no agency known to science which can be used to influence the rate of production of energy. Thus, if a radioactive material were used as a source of power, it would continue to function whether it were desired to use the power or not. This leads to the conclusion that the collision process (*b*) offers the only present hope of producing nuclear energy in a form suitable for application to rocket propulsion.

One example will serve to illustrate the nature of such a process: when a neutron ($_0n^1$) collides with a boron ($_5B^{10}$) nucleus, the latter disintegrates and the resulting products are a lithium ($_4Li^7$) nucleus, an α-particle ($_2He^4$) and the emission of 3×10^6 electron-volts of energy. This particular nuclear reaction is written:

$$_5B^{10} + {}_0n^1 \rightarrow {}_3Li^7 + {}_2He^4 + 3 \text{ M.e.v.}$$

There are a very large number of possible collision-reactions, among them the fission reaction of the atomic bomb and the thermonuclear reactions which power the stars.

A fundamental difficulty with the type (*b*) process is the need to satisfy certain critical conditions of mass in the reacting material; it is attributable to the very small size of atomic nuclei, the actual geometric cross-section of a medium-sized nucleus being about 10^{-24} square cm.* If a particle approaches a nucleus it must pass within a certain target area if it is to produce the given desired result; this target area is known as the cross-section† for that particular occurrence. The magnitude of the cross-section for a given process depends on the nature of the colliding particles and their relative velocity.

If the bombarding particles are charged (*e.g.* protons or deuterons), the probability of their passing within the prescribed cross-section is so small that on the average a high energy proton would have to traverse several metres thickness of matter before making a collision with the desired result. After covering only a fraction of a millimetre along such a path, however, it would be so slowed down that it would much more likely have captured a stray electron and become a harmless hydrogen atom; the relative probability of this result is usually much more than a million times greater than the former one.

* Nuclear cross-sections are normally measured in units of 10^{-24} cm.^{2}, this unit being called a BARN.

† The cross-section is, strictly speaking, a statistical quantity representing the probability that a given collision will result in the desired reaction. It is sufficient for our purpose, however, to regard each individual nucleus as possessing a definite target area, such that a reaction will occur only if the "bombarding" particle falls within the area.

It is this million to one chance against a proton or deuteron making an effective collision before being rendered harmless, which makes it so difficult to utilise nuclear reactions involving charged particles. We know of only one set of conditions under which such reactions may proceed. This occurs when the matter is at an extremely elevated temperature, in which case the protons or deuterons are never rendered completely harmless by slowing down. At $10^{6°}$ K. or higher temperatures we find that many protons will exist, in thermal equilibrium, with energies up to, and exceeding, 1,000 electron-volts, at which energy the particle is still capable of making an effective collision, though the cross-section is minute. Under such conditions a typical proton might exist for hundreds of millions of years and diffuse through thousands of kilometres of matter before making a lethal collision.

Reactions of the latter type are called *thermonuclear*, and they do in fact occur at the cores of the stars where the necessary elevated temperatures obtain. The stellar cores fulfil the necessary critical conditions of having large quantities of matter present, so that the rate of energy production in the nuclear collisions is sufficient to balance the heat losses from the core. It is difficult, however, to imagine such conditions being reproduced on a small scale, where they would be useful to our purpose.

Reactions involving neutrons can proceed under much more favourable conditions of size and temperature; in the first place, any free neutron, no matter what its initial energy, must end its career in a nucleus, since no combination with an electron is open to it. Furthermore, the required cross-sections for nuclear processes involving neutrons are often very large, frequently many thousands of times as great as the actual geometrical cross-sections of the nuclei. Thus, a neutron moving about in matter has only to move very small distances—sometimes only a fraction of a millimetre—before being absorbed by a nucleus. Unfortunately we know of no method of storing free neutrons and we may produce them only as a result of high energy nuclear processes, in contrast to the production of free protons and deuterons which requires only low energy electronic processes. Thus we cannot choose just any neutron reaction we please, but must select one of the few reactions in which each neutron absorption results in the production of one or more fresh neutrons to replace the one absorbed. The only known case for which this chain process of neutron multiplication occurs with evolution of energy is the fission reaction of certain heavy elements, which can be obtained only by costly transmutation or separation processes.

If pure fissile material (U^{233}, U^{235} or Pu^{239}) is employed, the critical condition for a reaction will be satisfied by a comparatively small bulk—a sphere of a few centimetres radius of solid material, for example. This is the "fast neutron" reaction of the atomic bomb. Alternatively, a controllable process is possible, using material which contains only a percentage of fissile substance. In this, the neutrons are slowed down by passage through a suitable material such as pure graphite or heavy water, known as the moderator. The moderator is chosen to have a low probability of capture of the neutrons traversing it, with good properties of reducing their speed, *i.e.* low atomic mass. Such a

"slow neutron" system releases energy at a slower rate, is inevitably characterised by much greater bulk, and is the basis of the current plans to produce atomic energy for industrial purposes. It must also, for the present, be submitted as the only promising basis of any project to apply atomic energy to rocket propulsion.

Since the release of nuclear energy is usually manifested by the ejection, from the reacting nuclei, of heavy particles with high velocities, it has often been suggested that such effects could be directly harnessed to produce a propulsive jet, which would be entirely composed of the particles concerned and which would have an effective exhaust velocity of the same order as the particle velocities. For example, in the case of the fission reaction the products of the nuclear disintegration are two or more particles which recoil at about 10,000 km./sec.

An exhaust velocity as high as this might seem, on first consideration, to be a complete solution to all the difficulties outlined in Section 1, but unfortunately other factors are present which rather spoil this attractive conclusion. In the first place, these particle velocities of the order of 10,000 km./sec. occur in completely random directions, and the various proposals for regarding them as potentially convertible to exhaust velocities contain no practical suggestions as to how this conversion might be arranged. In the second place, any such scheme runs into fundamental difficulties concerned with the amount of power dissipated in the system, except under certain restricted conditions.

Consider a rocket of instantaneous mass $= M_i$ moving with a true acceleration of ag, where g represents the gravitational acceleration at the Earth's surface. The thrust required is therefore $= M_i ag$, and if v_e is the exhaust velocity as before, we find that the jet power (rate of dissipation of exhaust kinetic energy per unit time) is given by:—

$$P = M_i ag.v_e \times \tfrac{1}{2}$$

or:

$$p = agv_e \times \tfrac{1}{2}$$
$$= 4{\cdot}9 \times 10^3 \times av_e \text{ kilowatts/tonne} \quad \ldots\ldots (I.3)$$

(N.B.—1 Kw. ≡ 1·34 British, or 1·36 metric, horsepower and of course 1 metric tonne ≡ 0·99 British ton. v_e measured in km./sec.)

In the above equation I.3, p is a very important quantity which we shall call the *specific exhaust power*; it represents the amount of power dissipation, per unit mass of the ship, which is necessary for a given acceleration. Note that this expression is related only to the *jet*; the power dissipation in the *motor* itself will be two or more times as great, due to the thermal inefficiency of the power unit, and nearly all the difference between these two quantities appears as heat—either residual heat left in the jet, or else communicated to the power unit and its coolant system. Now, a space-ship operating in the neighbourhood of the Earth, for example, ascending from its surface through its gravitational field, must have a, the non-dimensional factor of I.3, >1. Let us assume $a = 2$ (actually a true acceleration of only two gravities, *i.e.* "1g effective,"

would be quite a low value), and let us also assume that $v_e = 10{,}000$ km./sec., the order of exhaust velocity which might apply if we knew how to make direct use of nuclear energy. From equation I.3,* we then find that the jet power required for a 100 tonne ship (a minimum likely value) would be no less than $9{\cdot}8 \times 10^9$ kilowatts ($13{\cdot}2 \times 10^9$ H.P.)! A large proportion of this huge power would inevitably escape into the bulk of the rocket and in practice would vaporise it in a fraction of a second; this would particularly be the case for a nuclear-powered unit, in which much of the waste energy would appear as hard radiation. It is apparent that we must set our sights a little lower, and since the specific exhaust power is directly proportional to exhaust velocity, it seems probable that the first interplanetary voyages will be undertaken using power units giving v_e nearer to 10 km./sec. than 10,000 km./sec. Such a reduced value, still much greater than any possible from chemical propellants, will represent a much more economical, less dangerous and more easily handled, expenditure of power.

Before leaving this point, however, it seems desirable to draw attention to the fact that specific exhaust power is also directly proportional to a, *i.e.* to the acceleration employed. For a rocket moving in field-free space, it might be possible to employ "a" values measured in micro-gravities, rather than multiples of gravity. These were the "restricted conditions" referred to earlier, and we shall return to them in a later section of this paper.

The need to "water-down" the high exhaust velocities theoretically possible from the use of nuclear energy leads us at once to the appreciation of a means by which this should be possible. Just as nuclear energy cannot be used directly in industrial machines, but has to be used indirectly in "piles" or reactors, which communicate the available energy as heat to a working fluid (steam or gas), which can drive turbines, so it will be with rocket propulsion. In fact, the term "water-down" has an almost literal significance, since water is one of the working fluids which might be considered for such a system. Proposals for such an indirect means of utilising nuclear energy in rocket type motors have, of course, already been made by Alvarez, Ackeret, the present writers and various other people, including several authors from the California Institute of Technology.[1] The engineering difficulties involved are immense, but are of an order which it seems not unreasonable to assume may be surmounted in the foreseeable future.

In giving further more detailed consideration to such systems in the later sections of this paper, we shall refer to the intermediate working fluid employed as the *propellant*, while the source of nuclear energy will be called the *fuel*. At this stage, we shall merely consider briefly the expenditure of nuclear fuel required to produce a given exhaust velocity and discharge.

Let m_p be the total mass rate of discharge, including any nuclear fuel which may be ejected along with the propellant, and let m_f be the rate of expenditure of nuclear fuel.

* It is unnecessary to employ relativistic relations even for this high exhaust velocity, since it still represents only 0·033 × the velocity of light.

The exhaust power is then given by

$$P = m_p \cdot \frac{v_e^2}{2}$$

and the total dissipation of power in the propulsion unit will be

$$P' = \frac{m_p v_e^2}{2\eta}$$

where η is some factor $<$ unity which we may regard as the overall thermal efficiency of the unit (see earlier remarks).

Now the energy released in a given nuclear reaction is characterised by a decrease in mass. If we represent the fractional decrease in mass by a factor α, then the nuclear energy released from a reacting mass m_f is given by $\alpha c^2 m_f$ where c is a constant having the dimensions and magnitude of the velocity of light ($=3 \times 10^5$ km./sec.). Combining this with the previous result, we have:

$$P' = \frac{m_p v_e^2}{2\eta} = \alpha c^2 m_f$$

or:

$$\frac{m_f}{m_p} = \frac{1}{2\alpha\eta} \cdot \left(\frac{v_e}{3 \times 10^5}\right)^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots (I.4)$$

If the nuclear fuel is to be a fissile material such as Pu^{239}, we have α of the order of 10^{-3}. Taking η at the arbitrary but reasonable value of 0·5, we can therefore construct the following rough table:—

TABLE II

v_e (km./sec.)	m_f/m_p
10,000	1
1,000	10^{-2}
100	10^{-4}
10	10^{-6}

It is thus apparent that the lower exhaust velocities call for only a desirably small expenditure of fissile material, as far as energy requirements are concerned; the ejection of 1,000 tonnes of propellant requires only 1 kg. of fuel when $v_e = 10$ km./sec.

3.—Shielding, and Other Consequences of Radiation

The preceding Section 2 was intended as a preliminary survey of the problems concerned with applying nuclear energy to rocket propulsion, and no such discussion would be complete without some reference to radiation problems. Since these involve considerations of practical design features, rather than broad performance trends, any detailed study of them is outside the scope of the present paper. However, it is desired not to minimise the difficulties involved in attempting to develop any type of atomic rocket, from whatever source they are derived, and so the following very brief summary is included. (It is hoped to return to the subject in greater detail at a later date.)

The nuclear power unit would give off neutron and γ-radiation, the necessary shielding from which would fall into two categories:—

(*a*) Power shielding.

(*b*) Health shielding.

The first of these requirements would arise because the nuclear radiation leaving the power unit will inevitably carry away at least a few per cent. of the total energy generation of the unit, which (as we have already seen) represents a very large figure. The absorption of these radiations will, of course, result in the release of a considerable quantity of heat, and to prevent the initial layers of absorbing material from attaining excessive temperatures, they will need to be incorporated in the regenerative cooling system. (It is envisaged that the type of propulsion unit, arrived at as the most hopeful solution in the preceding section, would use its secondary working fluid (or propellant) as a coolant, to be circulated through a jacket surrounding the motor in a similar manner to that of current liquid-fuel rocket motors.) This "power shielding" would also probably need to shroud the power unit more or less completely.

The second category, "health shielding," would be needed to protect the crew of the ship from the lethal effects of the residual radiations which succeeded in passing through the "power shielding." Water or some other hydrogenous material would, perhaps, be the best material for the purpose, since water is an excellent absorber of neutrons, and of γ-radiation between the 2 and 5 M.e.v. energy region (which would probably be the most troublesome to remove). A very long, slender shape is indicated for an atomic rocket, with the cabin at the nose and the propulsion unit at the tail. In such a design the cabin would be in the radiation shadow of the lethal emissions from the power unit, and the necessary thickness of shielding material would need to be only a relatively small cross-sectional area, and hence weight. Also, the maximum length of path, through all the protective propellant tanks and structure, would have to be traversed by any radiation proceeding internally along the axis of the ship towards the cabin.

It can be shown that, by careful design along such lines as those suggested above, the necessary weight of shielding need not be prohibitive. It will always, however, be high, and will impose a minimum size below which it would be impractical to build an atomic rocket. (A similar trend is apparent from the need to satisfy criticality conditions in the power unit itself.)

Even the above formidable problems do not represent the end of our troubles from the radiation hazard, however. After the nuclear powered motor has been shut down, it will have a certain residual radio-activity which, as we saw in Section 2, cannot be reduced in intensity by any known means. Fortunately, the "power shielding," which must in any case surround the motor for cooling during its actual operation, should also provide sufficient protection from this residual radio-activity to ensure the safety of personnel who need to pass by the walls of the hull, near to the tail, after a landing. In certain possible types of power unit, however, the residual radio-activity

inside the motor may well prove an embarrassment for another reason; if the propellant flow were completely shut down, it is possible that the motor would overheat dangerously, simply because of the energy released by these residual radiations. If it proved impossible to cope with this cooling problem by other means, so that, once started, it was impossible to shut down again to zero thrust, it is obvious that such motors could have only a specialised usefulness. It may be, however, that one could contrive to shut them down within an acceptably short period, without attaining excessive temperatures.

Another difficulty, common to all attempts to apply atomic power in any form of machine, is the effect of radiations on the mechanical properties of the structures involved. The design of the nuclear-powered propulsion unit discussed here could in many respects be described as an engineering metallurgist's nightmare. Due to the intensive radiations traversing the motor, many transmutations would occur, so that the designer would have to consider the tensile strength and other mechanical properties, not only of the alloys from which the unit was built, but also of those which would compose its structure towards the end of its operational life! Other equally embarrassing effects would also occur.

Finally, it must be remembered that the exhaust stream from an atomic rocket would itself be radio-active. In any type of power unit which ejected even a small proportion of nuclear fuel along with its main mass of propellant this radio-activity would be quite violent. Direct take-off from the Earth's surface would, therefore, be unacceptable, and it seems almost certain that any space-ships with atomic drive will be at least two-step designs. The first of these steps would be a booster, used for take-off and initial climb through the atmosphere, and would use normal chemical propellants. A tail-first landing, of the type usually envisaged, would also be unacceptable in many, if not all, cases, if the descent were made wholly on atomic power. The radio-active jet would render lethal the area of the landing, so that, once again, at least the final stages would have to be made using chemical motors. It is even possible that these would have to be employed to give the first initial impulse separating the upper step (with atomic main motors) from the first or lower step used for take-off boost; alternatively, the booster step might have to fit small forward firing motors to decelerate itself and allow the atomic step to get clear before starting its jet, which otherwise would spray its own booster step, the latter probably itself containing a crew.

Even these brief remarks should serve to illustrate the truth of Dr. Alvarez' remarks quoted at the commencement of this paper; it is also apparent from the preceding paragraph that the chemical rocket motor will probably still find its place in the operation of any future space-ships deriving their main propulsion from nuclear power.

(To be continued.)

REFERENCE

(1) "The Physics of Rockets," by H. S. Siefert, M. W. Mills and M. Summerfield, published in issues Nos. 1, 2 and 3 of Vol. 15, *American Journal of Physics*, 1947.

THE PROBLEM OF DR. CAMPBELL

By A. C. CLARKE

Dr. J. W. Campbell is the President of the Royal Astronomical Society of Canada and for some years has taken a sceptical interest in space-flight. In 1941 he published a mathematical paper[1] in which he calculated that a space ship would need an initial weight of about 1,000,000,000,000 tons for the lunar return journey. This interesting and original result was obtained—apparently in complete ignorance of all the work that had been done on the subject over the previous 20 years—by assuming a "final" mass for the rocket of 500 tons (!) and an exhaust velocity of only one mile a second. That practical space-flight cannot be achieved *under these conditions* can easily be shown in a few lines, and does not require the several pages of mathematics employed by Dr. Campbell. However, his paper must have convinced many at the time that interplanetary travel was quite impossible.

Actually it proved nothing of the sort, for if one assumes sufficiently unfavourable initial conditions one can obtain even more fantastic figures. A spectacular example of this occurs in Goddard's first Smithsonian paper,[2] where it is shown that with the best fuels available a rocket would have to weigh 10 pounds to give a certain performance—whereas with the old-fashioned fuels and construction used in a type of marine rocket which Goddard was unkind enough to name, the initial mass would have to be six times that of the entire earth!

Dr. Campbell has now returned to the subject in an address entitled "The Problem of Space Travel," given to the Royal Astronomical Society of Canada at Toronto.[3] This is a non-mathematical talk, much of which is devoted to criticisms of newspaper and magazine articles on astronautics. There is still no indication that Dr. Campbell has read any technical studies of the subject, and one wonders what he would think of a critique of modern astronomy which was based largely on reports in the daily press.

The lecture opens with quotations *pro* and *con* astronautics by various writers, and it is a little unkind of Dr. Campbell to reproduce a polemic by F. R. Moulton, every single item of which was demonstrably incorrect even when it was published in 1935. (With what authority Dr. Moulton speaks on the subject may be judged from his calculation[4] that it would need the energy of 16,000 tons of coal at 100 per cent. efficiency to lift a 10-ton rocket 100 miles. The Germans are therefore greatly to be congratulated on producing rockets with an efficiency of several hundred thousand per cent.!)

After a short and lucid summary of the fundamental problems of astronautics, Dr. Campbell deals with various suggestions that have been put forward to overcome them. In particular he is critical of the idea (proposed by Ley and others) that the orientation of a space-ship could be altered by the rotation of internal masses. It is perfectly true, as Dr. Campbell points out, that the response of a space-ship to such momentum changes would be very sluggish, but he seems unaware of the fact that this does not matter. With a rather small, electrically driven flywheel, a rocket of V.2 size could be rolled

completely over in less than ten minutes—and there is no particular urgency about a manoeuvre which can be carried out at any time over a period of days or months! The alternative solution (much more usually mentioned and actually employed in the U.S. Navy's "Neptune") is not considered by Dr. Campbell. Tangential steering jets are quicker and the momentum change is permanent. A flywheel gradually restores the *status quo* as it runs down—unless one carefully edges it out through a convenient hatch, which is rather an expensive way to jettison angular momentum!

Dr. Campbell devotes some time to a critical discussion of "space-stations," but unfortunately much of his information appears to be culled from a well-written but hardly technical article in the American magazine, *Look*.[5] Most of his comments are, therefore, somewhat trivial, as they deal with matters which were discussed in great detail by Oberth, Noordung and von Pirquet 20 years ago.[6] Dr. Campbell pours scorn—as well he might—on *Look's* optimistic suggestion that anything as unwieldy as a space-ship could nose its way under its own power into "mooring sockets" on a probably spinning space-station. However, in calling the approach to the station a "trapeze act," Dr. Campbell should have pointed out that it can be done in slow motion, and the performers have a chance of repeating it if the first attempt fails!

The problem of making contact between two bodies in space seems to us considerably less difficult than that of refuelling in mid-air—which looks almost impossible on paper yet which has turned out to be surprisingly simple in practice. Having watched films of aircraft "snatching" grounded gliders, we consider that a few nylon cables should be able to neutralise any reasonable relative velocity, after which it would be merely a matter of manning the capstans!

It is difficult to see the grounds for Dr. Campbell's statement that "space-suits would have to be worn at all times," unless the station was manned by meteorophobes with a profound mistrust of statistics. (They might get that way, of course, after a long enough tour of duty!) Perhaps the highest co-efficient of irrelevancy, however, should go to the gloomy remark that, when it was eclipsed by the earth, the station would be "very difficult to see"—and hence, one presumes, to find. Dr. Campbell might be reassured on this point if he bothers to work out the visual range of a 100 watt bulb in free-space. But why *look* for a space-station, even in full sunlight, when the feeblest of radio beacons has a range of many thousand kilometers?

More important than these somewhat light-hearted comments (which it is perhaps unfair to take too seriously) is Dr. Campbell's discussion of fuel requirements. He admits that his originally assumed exhaust velocity (1 m.p.s.) was too low, and raises it to 2 m.p.s.—still a rather pessimistic ceiling even for chemical fuels. This at once reduces his mass-ratio from 2×10^9 to $4{\cdot}5 \times 10^4$, and this figure could be reduced still further by employing a higher initial acceleration. (Large mass-ratios are extremely sensitive to variations in the number of "g" used.) The figures, however, are still much too high to be practicably realisable, and Dr. Campbell then goes on to discuss a lunar voyage with a refuelling stop at a space-station 500 miles from the earth.

Here, we are grieved to say, Dr. Campbell obtains figures which are quite incorrect, owing to his cavalier treatment of vector quantities. He states that to reach the space-station from the earth's surface the rocket must attain velocities of 4·37 m.p.s. horizontally and 2·33 m.p.s. vertically—a total of 6·70 m.p.s. But, of course, one cannot add directed quantities in this way, and the actual velocity required is much lower. To put it somewhat crudely, the earth's gravitational field can cause the necessary 90 degree bend in the ship's path, without the rockets doing any work at all. The correct answer to the problem is found by considering the velocities in an ellipse touching the earth's surface and the orbit of the space-station, with one focus at the centre of the earth. Making allowance for transfer velocities, the figure is 4·9 m.p.s., which requires less than half the mass-ratio calculated by Dr. Campbell (11·5 as against 28·5). The remaining figures are incorrect by the same factor, but as there is little point in considering lunar voyages with a fuel of only 2 m.p.s. exhaust velocity we will not discuss them any further.

Dr. Campbell ends his paper with what is perhaps the unkindest cut of all:—"The descriptions available for many of the suggestions are lacking in detail." When one considers the scores of books and hundreds of articles in which every conceivable aspect of interplanetary flight has been discussed (often with Teutonic thoroughness) this remark seems more than a little ingenuous.

A postscript to the paper gives some criticisms of a booklet, *Atoms, Rockets and the Moon*, by Dr. Dinsmore Alter, many of which are justified since Dr. Alter's enthusiasm is almost as ill-informed as Dr. Campbell's lack of it. (The less said about Dr. Alter's spherical space-ships with helicopter screws the better.) But at least he errs in the right direction, even if his aero- and astro-dynamical ideas are somewhat strange.

When we had finished Dr. Campbell's paper we were haunted by that "I have been here before" feeling, and suddenly we realised why. We dug out our copy of Simon Newcomb's *Sidelights on Astronomy* and read these words, written some ten years before the Wrights flew, which should be an awful warning to scientists who make prophecies outside their field of special knowledge: "The demonstration that no possible combination of known substances, known forms of machinery and known forms of force can be united in a practicable machine by which men shall fly long distances through the air, seems to the writer as complete as it is possible for the demonstration of any physical fact to be."

Perhaps warned by this debacle, Dr. Campbell is less dogmatic and appears open to conviction. We would accordingly like to point out, as has been demonstrated so many times before, that the whole case for interplanetary flight rests on the possibility of attaining exhaust velocities considerably greater than 2 m.p.s.—in other words, on engineering rather than on astronomical considerations. It is therefore very significant that those who have had practical dealings with rockets (*e.g.*, von Braun at Peenemunde, Malina and Zwicky at C.I.T., to mention only a few) are very much more optimistic than Dr. Campbell. This illustrates the operation of a general law. The extreme enthusiasts and the extreme sceptics almost invariably have only a superficial

acquaintance with the subject. Those who have studied it for years realise, far better than most critics, the gravity of the problems which must be overcome; but they do not doubt the ability of the rocket to master them.

REFERENCES

(1) *Philosophical Magazine*, Jan., 1941.
(2) "A Method of Reaching Extreme Altitudes." (*Smith. Misc. Coll.*, LXXI, 2.)
(3) *Journal of the R.A.S. of Canada*, Mar.–Apr., 1948.
(4) Quoted by R. S. Richardson, Leaflet 201, Nov., 1945, *Astro. Soc. of Pacific.*
(5) *Look*, August 5, 1947.
(6) Oberth, "Wege zur Raumschiffahrt." Noordung, "Das Problem der Befahrung des Weltraums."

"BRAINS TRUST—2"

Following is a further selection of Questions and Answers which were put to the "Brains," consisting of Mr. J. Humphries, B.Sc., G.I.Mech.E., Mr. M. W. Ovenden, B.Sc., F.R.A.S., Mr. A. C. Clarke, and Mr. R. A. Smith at the meeting of the Society held in London on March 5, 1948.

After each question the meeting was invited to participate in additional discussion, and several of these answers have also been included.

Q.—What evidence is there that a form of matter can exist consisting of atoms with a negatively-charged nucleus, say of mesons, and neutrons with positively-charged positrons. Would this form of matter assume negative weight properties?

A.—According to modern theory, proton and neutron are regarded as two different states of a common particle known as a nucleon (so called because it is the fundamental brick with which the atomic nucleus is built). A proton is a nucleon in a state with positive charge and a neutron is one with zero charge. A neutral nucleon in a radioactive nucleus can be converted into a positive nucleon or proton by the emission of a negative β particle or electron, while a positive nucleon can go into a neutral state (neutron) by emission of a positive β particle or positron.

Theoreticians regard it as necessary that there should be yet a third state of nucleon, *viz.*: a state with negative charge. This would give us a so-called *negative proton*. It is possible that nuclei could be built up of negative protons and neutrons instead of the usual positive protons. Such nuclei would require positrons in the extra nuclear orbits to make up neutral atoms. However, it is by no means certain that such negative matter could exist, even assuming the existence of negative nucleons, for it is possible that all such nuclei would be unstable against emission of β particles.

It can be said with certainty, that the reversed matter which we have described, would have normal gravitational properties. The charge on a nucleon would not have any effect upon its behaviour in a gravitational field.

L. R. S.

Q.—Has the Moon magnetic poles?

A.—Once again the astronomer has to say, "We don't know." The spectroscopic techniques which are at present available for the detection of magnetic

fields are quitè unable to detect a field of the expected magnitude. In fact, one of the important observations that the first Lunar spaceship will make is the detection and measurement of such a field, if it exists. Certainly Blackett's recent formula connecting magnetic field and angular momentum, if it should prove to stand the test of further observation, would indicate that such a field must exist. M. W. O.

Q.—What are the views of the Brains Trust on flying saucers?

A.—Having been privileged, together with a million or so other readers of a well-known daily paper, to see a photograph of one of these strange manifestations, I must confess to being very sceptical as their objective reality. In fact, I think anyone may see a very plausible formation of flying saucers merely by glancing at the Sun without a dark glass.

Of course, it is a psychological fact that as soon as the possibility of seeing something unusual is suggested, a large number of people immediately see it. A similar state of affairs occurred recently with the bright southern comet that was predicted as becoming a naked-eye object in the northern hemisphere; soon after the publication of this prediction, the observatories at Oxford and Greenwich were almost flooded by letters and 'phone calls reporting observation of the comet in the western sky. Actually, the comet never did become a prominent object—what had been seen in all these cases was the planet Venus in its appointed place, bright enough to be seen almost with one's eyes shut. (Dr. Merton, of Oxford, tells the amusing story of the lady who, when asked how she knew that what she saw was the comet, said that it must have been because, as the evening wore on, it disappeared behind the trees.)

It is unwise to be dogmatic, particularly on a subject on which there have been so many conflicting reports, and it is possible that in the early reports something concrete was actually seen (possibly of meteoric origin, though I think this rather unlikely). However, I am sure that by far the majority of the "observations" were "physio-psychological delusions." M. W. O.

A.—I haven't examined the details carefully, but the "flying saucers" bear all the hall-marks of mass-suggestion. (H. Cantril's thesis on the Orson Welles' Broadcast—"Invasion from Mars"—provides the classic example of this. After the famous Mercury Theatre production of the "War of the Worlds," hundreds of people "saw" the invading Martians and took to the hills!)

One argument against the "flying saucers" being spaceships is the fact that 90 per cent. of the observations come from the United States. It is difficult to believe that a properly conducted expedition would so completely ignore the remaining, not-inconsiderable land area of this planet. A. C. C.

A.—I prefer to keep an open mind on matters where I do not have sufficient evidence to form an opinion. The reports so far to hand are conflicting, and there is no record of any observations by trained observers. Such picturesas have appeared might be meteors. There is also the possibility that the objects seen are in some cases subjective, and in some cases objective but inaccurately reported. One case appears to me to have been a "fire-ball" or coagulation of static electricity.

It is possible, but highly improbable, that these "flying saucers" are reconnaissance tenders sent for close inspection of the planet, by a visitor from deep space. It is quite rational behaviour to carry out a cautious short-range test of our defensive mechanism, and test out our reactions. I would advocate the same in approaching some other planet. If this is the case, then we should soon see the sequel. Provided no stupidity occurs, I see no reason for any nervousness even if that should prove to be so. As yet, however, I see no reason to assume that we have had our first intimation of Extraterrestial life. It is interesting to note that the flash of the atomic explosions in New Mexico, Hiroshima, Nagasaki, and Bikini, would be observable on the nearer planets, and an advanced intelligence there might think it time to take stock of the position here, in view of the fact that the flashes gave the spectrum of isotopes not found in nature.

I think it is far more probable that the appearance of the "flying saucers" betokens a return to normal in the press, and this is the first post-war "silly-season" which periodically affects the journalistic world when real news is hard to come by. R. A. S.

Q.—If the other planets are inhospitable, e.g. airless, with extreme temperatures, and so forth, what is the point in going there?

A.—Until someone has been to any particular planet, we shall not know whether it is worth visiting *again*, but the first trip is worth it to find out. Some of the places on this earth which are both desolate, and distant are visited regularly for one reason or another. If the original explorers had adopted the view that it would be wet at sea, hot in the tropics, and cold at the poles, they would not have discovered whales and seals, camels and pyramids, chewing-gum, potatoes and tobacco, cocoa, quinine, and all the strange things that come from distant places.

There is no point in climbing Mount Everest, or going to Central Asia to prove that Everest is not the world's highest peak. It is rather late in the day to try to defend the search for knowledge or to prove that things can be worth doing for their own sake.

If anyone who asks this question is prepared to let someone else go . . . then let that "someone else" be me. R. A. S.

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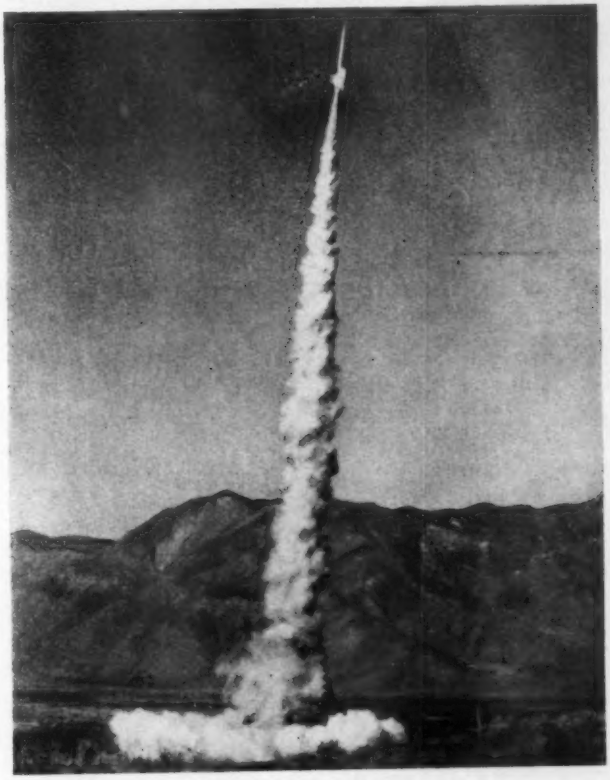
NOTES AND NEWS

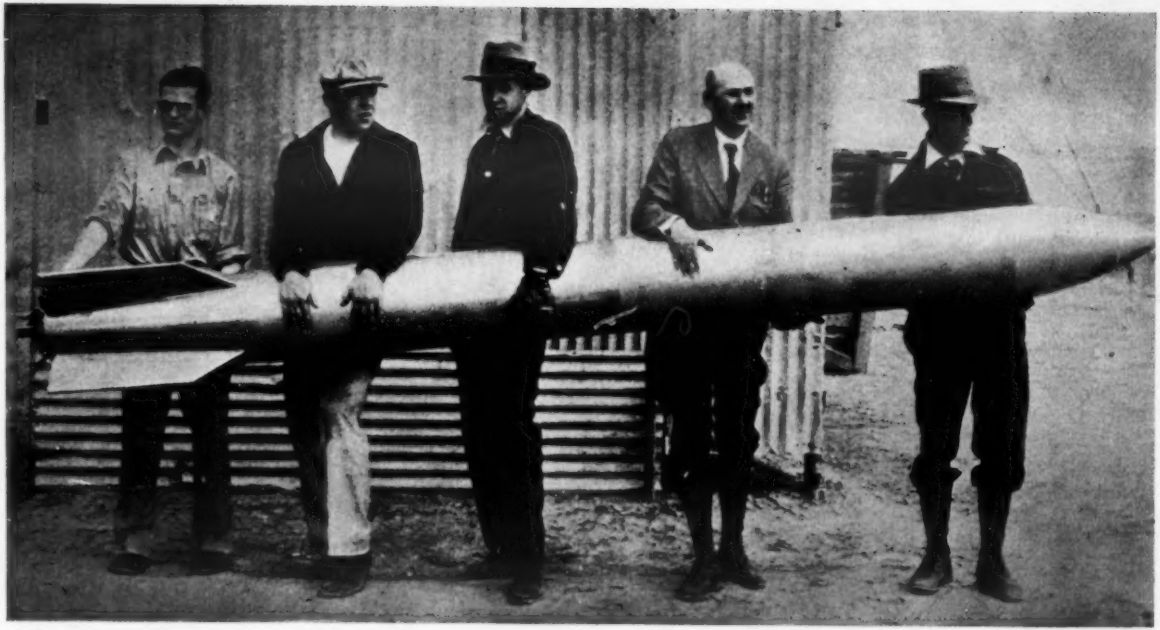
Earth's Magnetic Field Measurements

An attempt to obtain the first measurements at high altitude of the Earth's Magnetic Field was made on April 13 at White Sands Proving Ground, when instruments were included in the second "Aerobee" to be launched. This projectile duplicated the height of 78 miles recorded by the first rocket (ref. page 170, July *Journal*) on March 5.



First "Aerobee" leaving the launching rack.

Preliminary reports are that considerable data were obtained, but their value cannot be determined until a detailed analysis has been made. The three bodies co-operating in this research are the Applied Physics Laboratory of Johns Hopkins University, the Naval Ordnance Laboratory, and the Department of Terrestrial Magnetism of the Carnegie Institution.



One of the Goddard Rockets seen during experiments at Roswell, U.S.A.
(*Dr. Goddard is second from right.*)

Knowledge of the magnetic field at high altitudes is important in connection with the navigation of guided missiles in the future.

The "Aerobee," which has been designed primarily for upper atmosphere research, was developed by the Aerojet Engineering Corporation and Douglas Aircraft Co. It can carry 150 pounds of scientific recording instruments, and has a maximum speed of about 4,400 feet per second.

Goddard Exhibits

The American Museum of Natural History, in New York, has recently presented a Goddard Exhibit to commemorate the work of this noted pioneer of rocketry. A number of photographs, a rebuilt version of Goddard's first 1926 rocket, and the two actual rockets used in New Mexico in 1935, comprised the exhibit.

Willy Ley writes to say that the latter two rockets were tail drive designs about 15 feet long, burning petrol and liquid oxygen. The oxygen was fed by its own vapour pressure, but the petrol by a centrifugal pump driven by a nitrogen turbine; this was started on gaseous nitrogen but continued to run on liquid nitrogen, evaporated in a heat exchanger arrangement. A gyroscopic automatic pilot (controlling vanes in the exhaust and on the external fins, as on V.2) was provided, and landing was by parachute.

It will be remembered that one of the 1935 rockets attained an altitude of over 7,000 ft., while the 1926 experiments were the first known ascents with liquid propellant rockets.

Interplanetary Play

The play, *Ambassador Extraordinary*, which opened at the Aldwych Theatre on June 30, is of some interplanetary interest, since the ambassador in question is a Martian! We hasten to explain, however, that the connection with our subject is only a superficial one: the author (Mr. W. Douglas Home) has merely used the Martian's reactions to some of our terrestrial problems of life and politics to produce an original and diverting sophisticated comedy.

Members' Suggestions

We should like to remind members again that if they care to submit suggestions for articles in the *Journal*, future lectures, or if they have any interesting matter for correspondence or comments generally which they would like to make, these may always be addressed to the Secretary for consideration by the Council.

Confirmation of Bell XS-1 Supersonic Flights

U.S. Air Secretary S. Symington has confirmed that the rocket-propelled XS-1 aircraft has flown at speeds exceeding a Mach Number of one. The first pilot to exceed the speed of sound was Capt. Charles E. Yaeger on October 14, 1947. Since that date four other pilots have also made supersonic flights in the XS-1. No new speed or altitude records will be claimed for these flights as this would mean publication of figures. This the U.S. Air Force refuses to do on grounds of military secrecy. (*Aviation Week*, June 21, 1948.)

Nominations for Council, 1948-9

In accordance with the provisions of Article 14 of the Society's constitution the present Council will retire from office at the date of the Third Annual General Meeting to be held in December next, when a new Council to hold office for the ensuing session will then be elected.

Applications are invited for election to the Council during the Session 1948–9. Under the Society's regulations, any member may offer himself or propose another member for election.

Nominations should be notified as soon as possible, and in any event not later than October 31, 1948.

Loan of Articles from Periodicals and Journals

This scheme, announced in the March *Journal*, is now well under way. Already over 100 articles and patents are available on loan to members. Subjects covered include rocket-propelled aircraft, rocket motors, projectiles, aerodynamics, thermodynamics and jet propulsion. One interesting feature is an almost complete set of copies of Goddard patents. A complete list and details of the scheme can be obtained by sending 3d. in stamps to J. Humphries, Rodney House, London Road, Bicester, Oxon.

Strabismus has Rival!

We are indebted to the *News Chronicle* for information regarding 40-year-old Yun Gee, Chinese-American artist and an egg expert, who is looking for 12,000,000 men who are willing to work seven days a week for the next five years.

When he finds them, he will go to Washington and ask Congress for an appropriation of 300,000,000,000 dollars (£75,000,000,000), some aluminium and a lot of bamboo-ribbed canvas in 1,000-ft. sections.

Then he will build a tunnel to the moon.

Yun is working on the principle that a fresh egg can stand up by finding its own true axis. Dynamic gravitational forces come into effect and hold the egg upright.

His lunar tube would be built on the same principle.

A tube of aluminium, 30 miles high and on a platform supported by giant balloons, would channel up warm air from the earth. Inside, an extension of bamboo-ribbed canvas would float it upwards for 221,000 miles—right to the moon.

A really wide tunnel, says Yun, would allow planes to fly to the moon at 1,000 miles an hour; and if the project were really successful another tunnel, for return flights, could easily be built.

"I'm determined to go places," said Yun.

(We drew this to the attention of several of our technical members. The comment of our Technical Director was:

"The lunar project of Yun Gee
Is bound to fail because of 'g',"

whereas Mr. R. A. Smith replied "Are we being *bamboo*zled?")

ABSTRACTS

Edited by J. HUMPHRIES

Technical Thermodynamics of Dissociating Gases

(Otto Lutz. *LFF Hermann Göring, Braunschweig, ZWB/LFA.* U.S. Air Force, Trans. No. F-TS-997-RE. 79 pp., figs., refs.)

Graphical-mathematical methods for calculating the thermodynamic characteristics of dissociating gas mixtures. The tables for the mixture composition which are compiled give a synoptic view of the behaviour of dissociating gas mixtures at temperatures up to 4,000° K. The data from these tables, when the heat of dissociation of the compounds is taken into account, permit the formal representation of the changes of state of the dissociating mixtures by stoichiometric diagrams. By these it is also possible to express clearly the effect of the flow of the dissociating gases. The method is applied to combustion phenomena in general, the thermodynamics of rockets, and the cycle efficiencies in combustion engines. (From *Aeronautical Engineering Review*, Jan., 1948.)

Planetary Properties of Fast Cars

(A. F. Zahm. *Journal of the Franklin Institute*, April, 1948, Vol. 245, No. 4, pp. 331–6, tabs., refs.)

This article is as woolly as its title. It purports to give an elementary account of the mechanics of space-flight with special reference to artificial satellites. The author's modes of expression, as well as his ideas, are sometimes a little unusual. For example, "Or they (artificial satellites) could emit a trail of snow or white sand to create a moonlet, and return home for more. In due time they should put elegant rings round the earth rivalling Saturn's, yes?"

Little thought seems to have gone into either the material or the layout and the result is a third-rate "pot-boiler." It is amazing that a journal of such a high technical standing should have considered it worthy of publication.

A Pneumatic Method for Measuring High-Temperature Gases

(D. W. Moore, Jr. *Aeronautical Engng. Rev.*, May, 1948, Vol. 7, No. 5, pp. 30–4, illus.)

Gas temperatures that have to be measured today range from a maximum of perhaps 2,500° F. for turbo-prop installations to more than 8,000° F. for various rocket propulsion systems. The method of measurement described is based upon the well-known equations of flow of a gas through an orifice. Two orifices in series are used with cooling of the gas between them. The use of two orifices greatly simplifies the calculations, since such variables as the amount of sample gas flowing cancel out and thus do not need to be measured or controlled. The overall speed of response of the system is high and it can therefore be used as a means of control. Although the instrument is still in the development stage, test results to date have been encouraging and indicate that accuracies within 1 per cent. of the absolute temperature may be obtained.

Adiabatic Flow of Hydrogen Gas Through a Rocket Nozzle With and Without Composition Change

(S. S. Penner and D. Altman. *Journal of the Franklin Institute*, May, 1948, Vol. 245, No. 5, pp. 421–32, illus., refs.)

A procedure is described for determining the characteristics of adiabatic flow through a rocket nozzle with and without composition change. The method of calculation is illustrated for the expansion of pure hydrogen gas from a chamber temperature of 3,506° K. and a pressure of 20·42 atm. to atmospheric pressure. The study indicates that the exhaust velocity and temperature are highest for flow where complete equilibrium is reached at each temperature with respect to the reaction

$$H^2 \rightleftharpoons 2H.$$

Flow with composition change requires a nozzle exit to nozzle throat area ratio somewhat greater than that determined for adiabatic flow without composition change for the same ratio of chamber pressure to exit pressure.

The residence time in a given temperature range is computed as a function of gas temperature for the two types of flow. The results of this calculation may be used to determine the minimum required reaction rates which allow composition changes during flow through the nozzle.

Rocket Power

(E. Burgess. *Aeronautics*, May, 1948, Vol. 18, No. 6, pp. 38–50, illus., tabs.)

A clear and well-illustrated introduction to rocketry. The author outlines the uses of solid propellants and their limitations and continues with descriptions of the various types of liquid-propellant motor, together with details of fuel feed methods and injectors. In his last paragraph he rightly stresses the dangers of secrecy to the development of rockets for peaceful purposes.

Qualitative Experimental Verification of the Change of Burning Rate of Rocket Powders with Radiation Path Length

(S. S. Penner. *J. Applied Physics*, June, 1948, Vol. 19, No. 6, pp. 511–3, illus.)

Experimental studies on step-machined powder grains indicate a small increase in the average burning rate of solid rocket propellants with an increase in the radiation path length. This result is in agreement with theoretical predictions.

Effect of Radiation on the Rate of Burning of Solid Fuel Rocket Propellants

(S. S. Penner. *J. Applied Physics*, April, 1948, Vol. 19, No. 4, pp. 392-8, illus., tabs., refs.)

The temperature rise of powder grains in different rocket motors, resulting from the absorption of radiant energy, has been computed by the method of Avery. The calculated results show that more radiant energy is absorbed by the powder grains in large service rockets than in small experimental test

rockets. The increase in powder temperature before burning, associated with the absorption of radiant energy, leads to an increase in the average rate of burning of the solid fuel charge. The differences in burning rate produced by the absorption of radiant energy amount to less than 4 per cent. for the rocket motors commonly employed. Thus, burning rate results obtained in small test motors may be applied to predict the approximate behaviour of the same propellant in a large service rocket.

Tables for Numerical Solution of Problems in Compressible Gas Flow With Energy Effects

(A. H. Shapiro and G. M. Edelman. *J. Applied Mechanics*, June, 1948, Vol. 15, No. 2, pp. 169–75, tabs., refs.)

Tables of functions are given for solving problems in one-dimensional, compressible gas flow when energy effects, as represented by changes in stagnation temperature, are involved. The tables may be used for such typical processes as heat transfer at high gas speeds, combustion, moisture condensation shocks, flame fronts, and detonation waves. The Mach Number is the independent argument of the tables, and there is one table for each of six specific-heat ratios, namely, 1·0, 1·1, 1·2, 1·3, 1·4, and 1·67.

Mass Emissivity of Powder Gases in Solid Fuel Rockets

(S. S. Penner. *J. Applied Physics*, March, 1948, Vol. 19, No. 3, pp. 278–85, illus.)

An analysis has been carried out to determine an upper limit for the effective mass emissivity of the radiating gases in a solid fuel rocket motor. The calculations depend upon a comparison between experimentally observed performance data relating to a rocket motor and theoretical results based on a theory for the effect of radiation on the performance of solid fuel rocket motors. A simplified treatment is developed for correlating the rate of burning of the powder with the temperature rise of a powder grain caused by the absorption of radiant energy.

Interaction of Cosmic-Ray Primaries with Sunlight and Starlight

(By E. Feenberg and H. Primakoff, *Phys. Rev.*, March 1, 1948, Vol. 73, No. 3, pp. 449–69, tab., refs.)

This paper discusses collision processes between cosmic-ray primaries (protons and electrons) and the thermal photons of sunlight and starlight. In particular, electron-positron pair production and Compton scattering in interplanetary, intragalactic and intergalactic space are treated in detail. It is found that the number of collisions between primary particles and thermal photons in single traversals of the solar system and the local galaxy is not sufficiently large to cause either appreciable energy loss to the particles or appreciable production of secondary pairs and energetic scattered photons. The same statement holds for the primary protons even on an intergalactic scale. On the other hand, energetic primary electrons may experience a

sufficient number of Compton collisions in intergalactic space (travel time of the order of 2×10^9 years) to eliminate them effectively from the cosmic radiation reaching the neighbourhood of the Earth.

The stopping power for electrons of the observed interstellar radio frequency spectrum is also estimated and found to be comparatively large.

Radar Detection of Meteors

(Monthly Notices of *R.A.S.*, 1947, Vol 107, No. 2, pub. March, 1948)

This part of Monthly Notices contains three important papers on the above topic.

(i) *Radio Echo Observations of Meteors*, by J. P. M. Prentice, A. C. B. Lovell and C. J. Banwell (page 155).

Gives an account of the early investigations at Jodrell Bank which were designed to examine the relation between visual and radar observations, and includes an important discussion on the correlation between the two types of observations. It is a joint paper from the Meteor Section of the British Astronomical Association and the Physical Laboratories, Manchester University.

(ii) *Radio Echo Observations of the Giacobinid Meteors*, 1946, by A. C. B. Lovell, C. J. Banwell and J. A. Clegg (page 164).

Describes the use of the specially-designed aerial system for work on meteor showers. Important discussions on the height and size distributions of the meteors in the shower, and an analysis of the life-histories of the echoes and possible physical characteristics of the meteors. Also discussion of correlation between characteristics of shower from visual and radar observations.

(iii) *Radar Observations of the Giacobinid Meteor Shower*, 1946, by J. S. Hey, S. J. Parsons and G. S. Stewart (page 176).

Description of the work done by the Army Operational Research Group of the Ministry of Supply, with particular emphasis on the development of photographic methods of recording echoes. This has enabled geocentric meteor velocities to be obtained directly from the radar observations. Discussion on atmospheric retardation of meteors, and peculiarities of the life-histories of the echoes are also included.

Journal of the Pacific Rocket Society

(Vol. 2, No. 3, Winter, 1947–48, 12 pp., diags., photos.* Quarterly).

This issue is devoted to current P.R.S. activities and an introductory article states: " . . . the practical objective of the Society's experimental program is the development of new techniques and designs which may be demonstrated by small liquid fueled rockets. True, our efforts are dwarfed by the huge military projects; nevertheless the military has neither the leisure

* *Already circulated (under exchange arrangements) to Fellows of the Society.*

nor the inclination to investigate and develop economical designs and small auxiliary refinements peculiar to shorter range, strictly meteorological, 'work horse' rockets in which we are interested. Nor does there appear to be any governmental agency devoted to even drawing board consideration of non-military interplanetary travel."

Accounts follow of P.R.S. work with small liquid oxygen-propane rockets, one of which (XD-3, take-off weight 8·2 lb., thrust 25 lb.) ascended 2,250 ft. Reference is also made to designs for a larger rocket (XD-4), work on a 10 ft. model space-ship and launching tower, and to experiments with a self-consuming wooden motor (fed with liquid oxygen), which has been employed in booster steps. There is also included a short article on the electical fire-control system used at the P.R.S. test site in the Mojave desert, and several pictures of this area.

Journal of the American Rocket Society

(No. 73, March, 1948, 48 pp., diags., photos.* Quarterly).

This issue contains an account of the 1947 A.R.S. Business Meeting, with statements of finance, membership (total = 812), etc. Miscellaneous news and editorial matter includes references to turbojet aircraft and ramjet helicopters, as well as purely rocket items; there are also general articles on small solid propellant rockets available for projecting steel cables, suitable for life-saving, and on the "Present and Future of Rockets." The latter is a reprinted speech by D. A. Kimball, Vice-President of Aerojet, given at the A.R.S. Annual Dinner; Mr. Kimball outlined the scope of rocket applications and stressed the need for team-work by industry, academic research organisations and government agencies, with continued financial support from the State.

The main technical article is "The Acid-Aniline Rocket Engine" (Berggren, Ross, Young and Hawk, all of Aerojet). This propellant combination is shown to have advantages resulting from its high density. The rest of the paper is more general than its title would indicate, being an interesting discussion of the mechanical design features of rockets (turbo-pump and pressurised feed systems, valves, injectors, etc.)

In "Metallurgical Aspects in the Design of Rocket Motors," J. U. Nutt, of Reaction Motors, pleads for specialised research in this subject and discusses stainless steels, aluminium alloys, welding, high temperature effects, ceramics and sweat-cooling.

A short paper: "The Mass Ratio Problem," signed "J.R.R.," suggests that "Atomic energy will not make as much difference to rockets as it will to other forms of transportation." The argument submitted in support of this contention is that the rocket will still need to carry a large mass of working fluid to generate its propulsive jet, even if nuclear enegy is available as a prime source. A chart is given, showing mass ratio required to provide any given final flight velocity, for various exhaust velocities.

The *A.R.S. Journal* is now edited by Major James R. Randolph, familiar for his contributions to *Ordnance*, and some indications of renewed interest in space-travel seem apparent.

Rockets

(By Willy Ley, *Federal Science Progress*, Vol. I, 1947, No. 1, February, pp. 40–3 (Pt. I); No. 2, March, pp. 38–41; (Pt. II), No. 3, April, pp. 26–8 (Pt. III). All parts illustrated.)

This series reviews briefly the history and uses of rockets, both solid and liquid fueled. Solids are covered in Pt. I, V.2 and the White Sands sounding experiments in Pt. II, with a section on atmospheric strata, and Pt. III deals with rocket-propelled aircraft. Although containing no new information, the series is written in Ley's usual easy manner and should appeal to non-technical readers.

Tiamat NACA Research Missile

(*Aero Digest*, February, 1947, Vol. 54, No. 2, pp. 80, illus.)

"Tiamat" is a step rocket developed as a test model for future missiles. It is 14 ft. 4 ins. long, weighs 600 lb. and its flight speed is approximately 600 m.p.h. Its booster step produces 7,200 lb. thrust for 3½ seconds when the main motor takes over, giving 200 lb. thrust for 45 seconds. The missile is fully instrumented and carried telemetering equipment.

Ceramic Materials Show Promise for High Temperature Mechanical Parts

(By Joseph R. Bressman, *Maths. and Methods*, Jan., 1948, Vol. 27, No. 1, pp. 65–70, illus., tabs.)

A review of present status and future requirements. The main purpose of American research has been to develop ceramics that will permit operations at temperatures above 1500° F. The investigations have proceeded along two chief lines: (1) the development of solid ceramic shapes for high temperature parts such as gas turbine blades; and (2) the development of ceramic coatings to protect metals from corrosion at high temperatures. Both of these aspects are discussed and research results given.

Cosmic-Ray Bursts in the Upper Atmosphere

(By H. E. Tatel and J. A. Van Allen, *Phys. Rev.*, Jan. 1, 1948, Vol. 73, No. 1, pp. 87–8, illus., refs.)

On 29th July, 1947, a successful V.2 rocket carried a bundle of four automatically calibrated pulse ionisation chambers mounted in the rocket nose to an altitude of 100 miles. During the flight there were recorded 150 secs. of good quality telemetered data above 180,000 ft. A brief description of the equipment and results is given.

Other Papers Noted

Rocket Projectile. C. N. Hickman. U.S. Patent No. 2,440,271, April 27, 1948.

Rocket Projectile. L. A. Skinner. U.S. Patent No. 2,440,305, April 27, 1948.

British Rocket Station. The Chemical Age, Aug. 23rd, 1947, Vol. 57, No. 1467. p. 259. Short account of a visit to the rocket research station at Westcott.

"Bombproofs" for Rocket-Motor Tests. Power, Sept., 1947, Vol. 91, No. 9, p. 102, illus. Photos of G.E.C. test pits.

Twenty Minutes of Eternity. C. Goodlin. Air Trails Pictorial, Vol. 30, No. 4, Jan., 1948, pp. 20–23, 88–94, 7 illus. Description by test pilot of XS–1 rocket aircraft, its operating procedure and handling qualities.

Electronics for Cosmic Ray Experiments. B. Howland, C. A. Schroeder and J. D. Shipman. Naval Research Lab., Navy Dept., Rocket Sonde Section, Washington, D.C. Review of Scientific Instruments, Vol. 18, No. 8, Aug., 1947, pp. 551–556. Describes the circuits used in connection with cosmic ray telescopes fitted in V.2 research rockets.

Photographic Tracking of Guided Missiles. L. M. Biberman, S. E. Dorsey and D. L. Ewing. *Electronics,* July, 1948, Vol. 21, No. 7, pp. 92–5, illus. Description of optical methods used in triangulating on projectiles and missiles. These are synchronised by radio-links from a central timing standard. Complete automatic firing system including remote three-camera recording station described.

Impossibility of Projectiles from Points on the Earth Becoming Satellites of the Earth. E. Esclangon. *C.R. Acad. Sci.* (Paris), 225, 161–3, July 21, 1947. In French. Paper considers permanent artificial satellites to be launched from the Earth and shows that if air resistance is taken into account, the perigee distance must be equal to or less than the Earth's radius, and projectile would therefore return to the ground. Satellite could be formed if for a time it was self-propelled.

Conversion of Projectiles from the Ground into Permanent Satellites of the Earth. E. Esclangon, *C.R. Acad. Sci.* (Paris), 225, 513–15, Sept. 29, 1947. In French. Considers conditions under which a projectile might become a satellite of the Earth, either by a propulsion operating after passing the limits of air resistance, or by a timed explosion which enables fragments to fulfil these conditions. Limits of velocity and directions of motion are found.

Exploratory Cosmic Ray Observations at High Altitudes by Means of Rockets. J. A. Van Allen. *Sky and Telescope,* May, 1948, Vol. 7, No. 7, pp. 171–5, illus., refs. A revue of the results obtained from the American rocket trials during the past two years.

Sur les problèmes de l'évasion hors de l'attraction terrestre et de la gravitation autour de la Terre. R. Genty. *Comptes Rendus,* May 10, 1948, Vol. 226, No. 19, pp. 1510–2. Note deriving the equation of motion for a rocket in vertical flight taking into account variation of the gravitational constant.

Rocket Exploration. Endeavour. A. C. Clarke. April, 1948, Vol. 7, No. 26, pp. 70–4, graphs, illus., refs. A good general elementary review of rocket flight and its possibilities.

REVIEW

Thermodynamique des Systèmes Propulsifs à Réaction et de la Turbine à Gaz

(By Maurice Roy. 160 pp. Published by Dunod, Paris (1946). 546 francs.)

This publication presents a series of lectures given by Professor Roy in 1946 to the compressible fluids section at the Paris Centre d'Etudes Supérieures de Mécanique. The text covers the whole field of reaction propulsion power plants for aircraft—turbojets, ramjets, ducted fans, even jet drives for helicopter rotors; all are discussed, but the special emphasis is on the gas turbine members of the family.

Chapter III (13 pp.) is devoted to a brief survey of the propulsive and themodynamic theory of rockets; it is too brief to be recommended as a reference for that specialised purpose, in preference to any one of a dozen more comprehensive sources purely concerned with rockets. However, the value of Professor Roy's latest book lies rather in its broad approach to the study of propulsive power plants in general, and the way in which it clearly sets forth the relationships between the various types—their fundamental common principles and their differences.

In this respect, the present work has obviously developed from an earlier one, produced by the same author in 1930. (*"Recherches Théoriques sur le rendement et les conditions de réalisation des Systèmes Motopropulseurs à Réaction."*) This had the distinction of being one of the very earliest technical references dealing with the possibilities of the type of aero-engine which we now call a turbojet. It is interesting to note that, in 1930, Roy proposed the name "turbo-fusée" ("turbo-rocket") for such power plants; they are now called "turboréacteurs" in his native France. A. V. C.

FORTHCOMING MEETINGS

We intend to introduce a regular feature on this page to remind members of forthcoming meetings, and particularly to bring to the notice of provincial members details of lectures which may be given in their locality.

If any members would like to attend meetings other than those delivered to this Society, they should write to the Secretary to enquire if permission could be obtained, or approach the other society direct.

Members are reminded that they are at liberty to introduce guests to the Society's own meetings whenever desired, and may obtain additional copies of the current lecture programme on request.

October 6, 1948 (Wednesday), 6 p.m. A lecture on Interplanetary Flight, to the Weybridge (Surrey) branch of the Royal Aeronautical Society at Vickers Works, Weybridge, by A. V. Cleaver.

October 9, 1948 (Saturday), 6 p.m. "INTERPLANETARY MAN," by Olaf Stapledon, to the Society at St. Martin's School.

October 13, 1948 (Wednesday), 5.45 p.m. "ROCKETS AND THEIR APPLICATIONS," by J. Humphries, to Ericssons (Foremen's Association), Beeston, Nottingham.

November 13, 1948 (Saturday), 6 p.m. "ORBITAL BASES," by H. E. Ross, to the Society at St. Martin's School.

November 17, 1948 (Wednesday). A lecture on Interplanetary Flight, to the Association of Engineering and Shipbuilding Draughtsmen at Luton, by A. V. Cleaver.

December 8, 1948 (Wednesday), 7 p.m. A lecture on Interplanetary Flight, to the Southampton (Hants.) branch of the Royal Aeronautical Society at University College, Southampton, by A. V. Cleaver.

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